THE STREAM NETWORK TEMPERATURE MODEL (SNTEMP): A DECADE OF RESULTS

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ABSTRACT

The National Biological Service's Stream Network Temperature Model (SNTEMP) is described briefly and some study applications are referenced.

Keywords: Water temperature model, SNTEMP, SSTEMP, Mathematical models, Thermodynamics

INTRODUCTION

The Stream Network Temperature Model (SNTEMP) was developed to help aquatic biologists and engineers predict the consequences of stream manipulation on water temperatures. Water temperatures may affect aquatic systems in many ways, ranging from acute lethal effects, to modification of behavioral cues, to chronic stresses, to reductions in overall water quality. Manipulations may include reservoir discharge and release temperatures, irrigation diversion, riparian shading, channel alteration, or thermal loading. The model has been used to help formulate instream flow recommendations, assess the effects of altered stream flow regimes, assess the effects of habitat improvement projects, and assist in negotiating releases from existing storage projects.

SNTEMP's development was a cooperative effort between the Soil Conservation Service and the U.S. Fish and Wildlife Service as one component of the Instream Flow Incremental Methodology (IFIM; Stalnaker et al., 1995). The design criterion was to produce reasonable predictions with readily available data; the result was the SNTEMP (Theurer et al., 1984). Later, an offshoot of SNTEMP, the Stream Segment Temperature Model (SSTEMP) was developed by Bartholow (1990).

DATA REQUIREMENTS

SNTEMP is a mechanistic, one-dimensional heat transport model that predicts the daily mean and maximum water temperatures. Net heat flux is calculated as the sum of heat to or from long-wave atmospheric radiation, direct short-wave solar radiation, convection, conduction, evaporation, streamside vegetation (shading), streambed fluid friction, and the water's back radiation. SNTEMP requires that the spatial layout of the hydrologic network be defined by

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subdividing it into stream segments with homogeneous characteristics such as flow, width, and shading. Each homogeneous stream segment is described by its length, top width, slope, channel roughness (Manning's n) or travel time, and shading characteristics. The meteorological influences are described by air temperature, relative humidity, wind speed, percent possible sun (inverse of cloud cover), and ground-level solar radiation. The flow of surface and ground water into each stream segment, along with their respective water temperatures, are also required inputs. The full list of data requirements is given by Bartholow (1989).

SNTEMP APPLICATIONS

SNTEMP has been used in a variety of applications. Theurer developed SNTEMP using two case studies to ensure model applicability and match with the development objectives (Theurer et al., 1982, 1985). These ranged over two scales: the vast upper Colorado River basin and the smaller Tucannon River. Since maturation, the model has been used widely, especially by consultants dealing with biological flow requirements in bypass reaches below hydropower facilities (Lifton et al., 1985, 1987; Voos et al., 1987). SNTEMP has been used in a broad range of applications, from the cold water of Alaska (Meyer et al., 1983) to the much warmer water of Nebraska (Dinan, 1992). The model has also been applied in less conventional situations, such as evaluating standards for streamside timber removal (Sullivan et al., 1990), revegetation requirements to increase shading and channel restoration (Bartholow, 1991, 1993), and channel manipulation to increase salmon rearing habitat by removing vegetated berms (Zedonis, 1994). SNTEMP has even been used below a peaking hydro facility (Waddle, 1988), something it was not designed to do. Increasing use of SNTEMP in conjunction with fish population models seems to be a recent trend (Bartholow et al., 1994).

SSTEMP, the offshoot model, is extremely easy to use because of its similarity to commonly available spreadsheet applications. The ability of both models to calculate solar radiation and streamside shading has also proven to be a strength; many other water temperature models do not have this capability. Even if the heat flux and heat transport components of SNTEMP are not used in a specific application, the solar and shade submodels may be used with other temperature modeling approaches (Sullivan et al., 1990; Tu, 1991; J. Risley, U.S.G.S. Portland, personal communication). Components of the models have been well validated (Theurer and Voos, 1982; Theurer, 1985; Mattax and Quigley, 1989; Bartholow, 1993), and their performance has compared favorably in side-by-side evaluations with other water temperature models ranging from simple to more complex (Sullivan et al., 1990, Tu and Liu, 1992).

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